USAARL Report No. 2002-16

Impulse Noise Levels of the UH-60A/L Black Hawk Helicopter Cockpit Air Bag System – Enhanced Lateral Air Bags

by William A. Ahroon, Elmaree Gordon, and Frederick T. Brozoski

Aircrew Protection Division

July 2002

U S A A R L

U.S. Army
Aeromedical Research
Laboratory

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), 8725 John J Kingman Road, Suite 0944, Fort Belvoir, Virginia 22060-6218. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about Laboratory reports.

Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release, distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
USAARL Report No. 2002-16

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
U.S. Army Aeromedical Research Laboratory

6b. OFFICE SYMBOL (*If applicable*)
MCMR-UAD

7a. NAME OF MONITORING ORGANIZATION
U.S. Army Medical Research and Materiel Command

6c. ADDRESS (*City, State, and ZIP Code*)
P.O. Box 620577
Fort Rucker, AL 36362-0577

7b. ADDRESS (*City, State, and ZIP Code*)
504 Scott Street
Fort Detrick, MD 21702-5012

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL (*If applicable*)

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS (*City, State, and ZIP Code*)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
622787	878	323	DA366714

11. TITLE (*Include Security Classification*)
(U) Impulse noise levels of the UH-60A/L Black Hawk helicopter cockpit air bag system - enhanced lateral air bags

12. PERSONAL AUTHOR(S)
William A. Ahroon, Elmaree Gordon, Frederick T. Brozoski

13a. TYPE OF REPORT
Final

13b. TIME COVERED
FROM TO

14. DATE OF REPORT (*Year, Month, Day*)
2002 July

15. PAGE COUNT
30

16. SUPPLEMENTAL NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
01	03	

18. SUBJECT TERMS (*Continue on reverse if necessary and identify by block number*)
Cockpit Air Bag System, CABS, UH-60A/L, Black Hawk, impulse noise, air bag, airbag

19. ABSTRACT (*Continue on reverse if necessary and identify by block number*)
A Cockpit Air Bag System (CABS) is being developed for the UH-60A/L Black Hawk helicopter. Earlier aeromedical evaluations of CABS revealed a potential injury risk associated with the lateral air bag component. An enhanced lateral air bag was developed and a series of 12 deployment tests was conducted. Impulse noise levels ranged from 144.8 dB peak sound pressure level (SPL) to 162.4 dB peak SPL with B-durations up to 172.6 ms. Although each air bag deployment resulted in impulse noise levels exceeding the 140 dB peak SPL limit specified by U.S. Army guidelines, since rotary-wing aircrew and passengers are required to wear hearing protection, no increased risk to hearing is anticipated from a single deployment of the CABS enhanced lateral air bag.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL
Chief, Science Support Center

22b. TELEPHONE (*Include Area Code*)
(334) 255-6907

22c. OFFICE SYMBOL
MCMR-UAX-SI

Acknowledgments

This research was funded by the Product Manager, Aircrew Integrated Systems (PM–ACIS), U.S. Army Aviation and Missile Command, Huntsville, Alabama. The authors acknowledge B. Joseph McEntire of the U.S. Army Aeromedical Research Laboratory for directing the aeromedical evaluation of the UH-60 Cockpit Air Bag System. We also thank SGT Joe Best for his support of the data collection aspects of this study.

Table of contents

List of figures

Table

Introduction

A Cockpit Air Bag System (CABS) has been developed for use in the UH-60A/L Black Hawk Helicopter by the U.S. Army Program Executive Office, Aviation Aircrew Integrated Systems. An aeromedical evaluation of the original UH-60 CABS was performed by the U.S. Army Aeromedical Research Laboratory (USAARL). The evaluation included an evaluation of the impulse noise levels generated by air bag deployment in six locations in the UH-60 cabin and was reported by Gordon and Murphy (2000). In a series of 21 air bag deployments, peak sound pressure levels (SPL) ranged from 134 dB to 161 dB with these levels exceeding the maximum allowable 140 dB peak SPL in the pilot, copilot, and gunner stations in all 21 deployments. Levels in the passenger compartment exceeded the maximum allowable level on nine of the 21 deployments. Since the UH-60 crew is required to wear flight helmets which provide impact and hearing protection and passengers are required to wear hearing protection, it was felt that this protection was sufficient to protect the occupants from hearing damage as the result of a single air bag-deployment event (i.e., single- or multiple-bag deployment).

Initial evaluation of the original CABS design focused on the possibility of an inadvertent or unnecessary deployment of the CABS and revealed a high risk of injury to the upper extremities from the lateral air bag (McEntire et al., 1999). Subsequently, the air bag developer has enhanced the lateral air bag module design in an effort to mitigate this injury risk. The Product Manager, Aircrew Integrated System (PM-ACIS) requested USAARL conduct a second aeromedical evaluation to assess the enhanced lateral air bag module.

This report describes impulse noise levels resulting from the enhanced lateral air bag during twelve deployments.

Materials and methods

PM-ACIS provided twelve enhanced lateral air bag modules for testing – six left-side and six right-side lateral air bags. These air bags were production-representative versions of the UH-60 enhanced lateral air bag (Figure 1). The air bag modules were installed and tested in a UH-60 aircraft assigned to the U.S. Army Aviation Technical Test Center (USAATTC), Cairns Army Airfield, Alabama.

In all tests, a 5th percentile female Hybrid III-type aerospace anthropomorphic test device (ATD) (manufactured by First Technology Safety Systems[*]) with a Society of Automotive Engineers 5th percentile female instrumented upper extremity (manufactured by R.A. Denton, Inc.) was seated in the cockpit of the UH-60A aircraft. The ATD was dressed in representative aircrew attire including a one-piece Nomex® flight suit, SRU-21/P survival vest, and an SPH-4 flight helmet (Figure 2) and was always located on the side adjacent to the deploying lateral air bag.

[*] A list of manufactures is provided in Appendix B.

Figure 1. Deployed enhanced UH-60 lateral air bag, viewed from the nose of aircraft.

Figure 2. Typical test setup. Shown is the ATD dressed in flight suit, SRU-21/P survival vest, and SPH-4 flight helmet

Impulse noise measurements were made using four Susquehanna Instruments (now PCB Piezotronics, Inc.) Model ST-2 pressure transducers mounted at grazing incidence on either side of the pilot's and copilot's seat (see Figure 3). The signals from the transducers were conditioned and amplified (10x) using a PCB Model 442B104 4 channel ICP® Sensor Signal Conditioner with Model 441A102 CD Power Supply. An IOtech Wavebook/516 with WBK30 128-Mbyte memory option digitized the signals at 160,000 samples per second per channel. A WKB15 multi-purpose signal conditioning module modified with front-panel BNC connectors with 9-pole Bessel filter, 40 kHz low-pass cutoff frequency, 5B modules (Frequency Devices Model 5BAF-LPBE9-40.0 kHz) installed provided the appropriate analog filtering in accordance with (IAW) Military Standard (MIL-STD) 1474D (Department of Defense, 1997) Noise Limits. A 500 ms pre-trigger duration and 1000 ms post-trigger were collected and transferred to a laptop computer via a WBK20 PC-Card/EPP interface for off-line analysis.

The data acquisition system was calibrated with an acoustic reference signal, produced by a Brüel & Kjær (B&K) Type 4220 pistonphone to provide sound pressure levels referenced to 20 micropascals (µPa) through a B&K Type 4165 ½ inch microphone. The microphone was powered and conditioned by a B&K Type 2639 preamplifier. Pressure transducers were calibrated using an acoustic signal produced by a B&K Type 4221 High Intensity Calibrator, referenced to 2 µPa (160 dB). The reference signals were analyzed and stored in data files on the control computer. The system was housed in an air-conditioned mobile research van for portability to the test site.

Analyses were performed with custom-written software to compute the positive peak pressure (in Pa and dB SPL), and the A- and B-durations of the impulse.

Results and discussion

Peak pressures at all recording locations were orderly with higher peak pressures present at the ear location closer to the deployed air bag. Summary statistics are reported in the Table. Individual deployment analyses are reported in Appendix A, Tables A-1 and A-2. Peak pressures ranged from 144.8 dB peak SPL (test RLAT11 Copilot left ear) to 162.4 dB peak SPL (test LLAT07 Copilot left ear) with B-durations up to 172.6 ms (test LLAT06, Copilot right ear). These levels exceed the 140 dB exposure limit defined by MIL-STD-1474D.

Figure 4 illustrates the peak SPLs and B-durations for impulse noise from MIL-STD-1474D Noise Limits. As noted above, each of the 48 exposures (12 deployments × 4 transducer positions) exceed the 140 dB Impulse Noise Limit W. Only three of the 48 measurements exceeded 160.5 dB and only one of these exceeds the Impulse Noise Limit X but is below Noise Limit Y (LLAT07, Copilot, Left ear, 162.4 dB peak SPL, 121.48 B-duration). Given that the pilots are wearing at least single hearing protection in the form of the HGU-56/P Aircrew Integrated Helmet System (IAW TM 1-1520-237-10 [Department of the Army, 1999], usually with dual protection consisting of an earplug or CEP), the impulse noise exposure from a single inadvertent enhanced lateral air bag deployment is not hazardous to hearing.

Figure 3. Typical pressure transducers used in the CABS deployment tests. Transducers are oriented at grazing incidence and positioned near the pilot's and copilot's left and right ear locations. Photograph from Gordon and Murphy (2000).

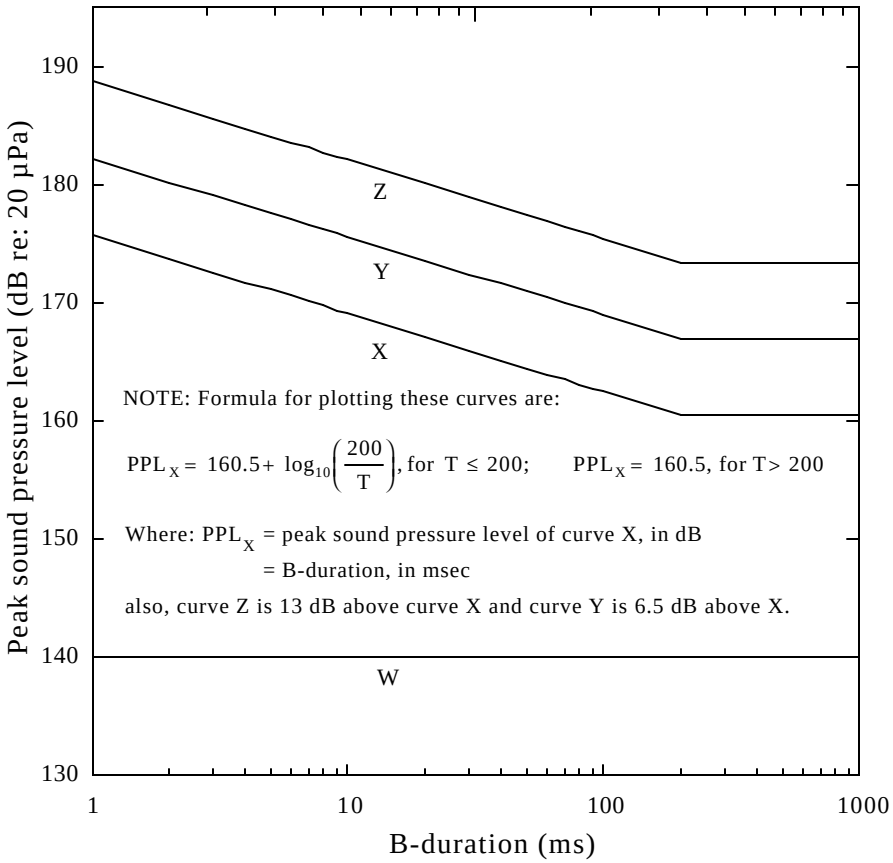

Figure 4. MIL-STD-1474D peak sound pressure levels and B-duration limits for impulse noise.

Table.
Summary statistics for acoustic analysis of enhanced lateral air bag deployments.

Air Bag	Crew Position	Ear Location		SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-dur (ms)	B-dur (ms)
Left	Pilot	Right	Mean	148.1	0.512	-0.679	1.30	60.67
			s	1.3	0.077	0.176	0.92	3.26
			Median	148.1	0.510	-0.657	1.26	59.79
Right	Pilot	Right	Mean	157.1	1.486	-1.476	0.88	45.27
			s	2.6	0.426	0.482	0.62	13.19
			Median	157.6	1.528	-1.466	0.75	42.60
Left	Pilot	Left	Mean	149.8	0.631	-0.692	1.01	30.03
			s	2.0	0.139	0.132	0.79	64.05
			Median	149.8	0.617	-0.693	0.62	58.45
Right	Pilot	Left	Mean	153.9	1.004	-0.908	0.64	47.16
			s	1.4	0.170	0.207	0.32	13.55
			Median	153.3	0.924	-0.814	0.62	46.46
Left	Copilot	Right	Mean	154.1	1.073	-1.033	0.89	66.16
			s	3.3	0.404	0.175	0.69	53.83
			Median	153.9	1.025	-1.061	0.68	48.81
Right	Copilot	Right	Mean	148.9	0.583	-0.653	1.59	57.81
			s	3.0	0.203	0.108	1.07	3.71
			Median	149.0	0.567	-0.628	1.23	57.15
Left	Copilot	Left	Mean	159.4	1.927	-1.669	1.05	52.17
			s	2.6	0.572	0.260	0.66	34.26
			Median	159.1	1.798	-1.586	1.03	39.57
Right	Copilot	Left	Mean	147.9	0.511	-0.618	1.58	68.68
			s	2.4	0.144	0.134	1.10	25.65
			Median	147.9	0.499	-0.609	1.30	57.40

Conclusion

Personnel exposed to impulse noise levels above 140 dB peak SPL are required to use hearing protection for exposure criteria defined by the Department of the Army Hearing Conservation Criteria (Department of the Army, 1998). Since current Army policy requires aircrew in the UH-60 rotary-wing aircraft to wear flight helmets that provide both impact and sound protection, and passengers are required to wear at least hearing protection in the form of earplugs or muffs, the impulse noise levels from deployment of the CABS enhanced lateral air bag does not pose an additional risk of hearing loss to the crew or passengers.

References

Department of the Army. 1998. Hearing Conservation Program. Washington, D.C. DA Pamphlet 40-501.

Department of the Army. 1999. Technical Manual Operator's Manual for UH-60A Helicopter, UH-60L Helicopter, EH-60A Helicopter. Washington, D.C. TM 1-1520-237-10, Change 4.

Department of Defense. 1997. Noise Limits. Washington, DC. Military Standard 1474D (MIL-STD-1474D).

Gordon, E. & Murphy, B A. 2000. Impulse noise levels of the UH-60A/L Black Hawk Helicopter Cockpit Air Bag System. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory, USAARL Report No. 2000-24.

McEntire, B.J., Alem, N.M., Gordon, E., Johnson, P. 1999. Predicting airbag-related injury using anthropometric test devices. Proceedings of the Workshop *Inflatable Restraints in Aviation Conference*, pp 142-149, Huntsville, AL, 1 - 3 December 1999. In Crowley, J.S. and Dalgard, C.L. (eds). Proceedings of the Technical Cooperative Program Workshop: Inflatable Restraints in Aviation. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory, USAARL Report No. 2000-21.

Appendix A.

CABS enhanced lateral air bag deployment pressure-time histories, peak impulse noise levels, and impulse durations.

Tables A-1 and A-2

and

Figures A-1 through A-12

Note: The waveforms were plotted using not less than ± 1.0 kPa and not more than ± 3.0 kPa scaling.

Table A-1

Peak levels and durations during deployment of the left modified lateral air bags at the locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
LLAT06						
	Pilot left ear	151.5	0.753	-0.801	2.21	-
	Pilot right ear	149.8	0.618	-0.986	0.21	66.56
	Copilot left ear	157.0	1.418	-1.426	1.78	42.99
	Copilot right ear	156.1	1.271	-1.016	0.63	172.63
LLAT07						
	Pilot left ear	152.1	0.807	-0.847	0.73	35.81
	Pilot right ear	148.2	0.515	-0.569	0.54	58.36
	Copilot left ear	162.4	2.635	-2.127	0.06	121.48
	Copilot right ear	151.8	0.778	-0.729	0.16	62.01
LLAT08						
	Pilot left ear	150.4	0.665	-0.648	0.51	59.52
	Pilot right ear	148.1	0.505	-0.702	0.71	58.16
	Copilot left ear	158.9	1.755	-1.585	0.66	44.43
	Copilot right ear	156.3	1.310	-1.174	0.63	33.09
LLAT09						
	Pilot left ear	149.0	0.562	-0.739	0.37	57.39
	Pilot right ear	149.2	0.578	-0.613	2.35	61.23
	Copilot left ear	159.3	1.841	-1.588	0.96	35.34
	Copilot right ear	158.4	1.672	-1.208	0.72	31.59
LLAT10						
	Pilot left ear	149.1	0.569	-0.482	0.45	61.88
	Pilot right ear	146.6	0.426	-0.475	2.19	61.49
	Copilot left ear	156.3	1.312	-1.478	1.75	36.15
	Copilot right ear	150.9	0.699	-0.965	2.18	37.76
LLAT11						
	Pilot left ear	146.6	0.429	-0.638	1.81	64.59
	Pilot right ear	146.7	0.432	-0.730	1.81	58.23
	Copilot left ear	162.3	2.603	-1.813	1.10	32.63
	Copilot right ear	151.0	0.708	-1.106	1.04	59.87

Table A-2

Peak levels and durations during deployment of the right modified lateral air bags at the locations shown.

Test	Location	SPL (dB)	P-Peak (kPa)	N-Peak (kPa)	A-duration (ms)	B-duration (ms)
RLAT06						
	Pilot left ear	155.7	1.213	-1.303	0.56	31.91
	Pilot right ear	157.0	1.409	-1.465	1.78	48.74
	Copilot left ear	151.5	0.748	-0.844	0.88	120.26
	Copilot right ear	153.3	0.926	-0.763	0.56	52.36
RLAT07						
	Pilot left ear	153.1	0.902	-0.831	1.09	60.93
	Pilot right ear	154.8	1.094	-0.920	1.36	58.61
	Copilot left ear	148.1	0.507	-0.632	3.08	56.66
	Copilot right ear	149.7	0.608	-0.645	0.79	57.23
RLAT08						
	Pilot left ear	155.8	1.226	-0.972	0.46	33.48
	Pilot right ear	158.3	1.648	-1.663	1.06	36.46
	Copilot left ear	149.3	0.581	-0.655	1.72	56.53
	Copilot right ear	150.4	0.663	-0.798	1.05	57.07
RLAT09						
	Pilot left ear	152.4	0.835	-0.774	0.88	63.73
	Pilot right ear	153.6	0.957	-1.062	0.45	62.08
	Copilot left ear	145.8	0.392	-0.551	2.68	58.14
	Copilot right ear	146.4	0.416	-0.612	2.44	60.46
RLAT10						
	Pilot left ear	153.2	0.911	-0.771	0.17	42.39
	Pilot right ear	158.5	1.689	-2.279	0.29	30.46
	Copilot left ear	147.8	0.491	-0.440	0.73	66.69
	Copilot right ear	148.4	0.527	-0.515	3.30	63.24
RLAT11						
	Pilot left ear	153.4	0.937	-0.796	0.69	50.53
	Pilot right ear	160.5	2.120	-1.466	0.32	35.26
	Copilot left ear	144.8	0.346	-0.587	0.42	53.77
	Copilot right ear	145.1	0.359	-0.588	1.40	56.49

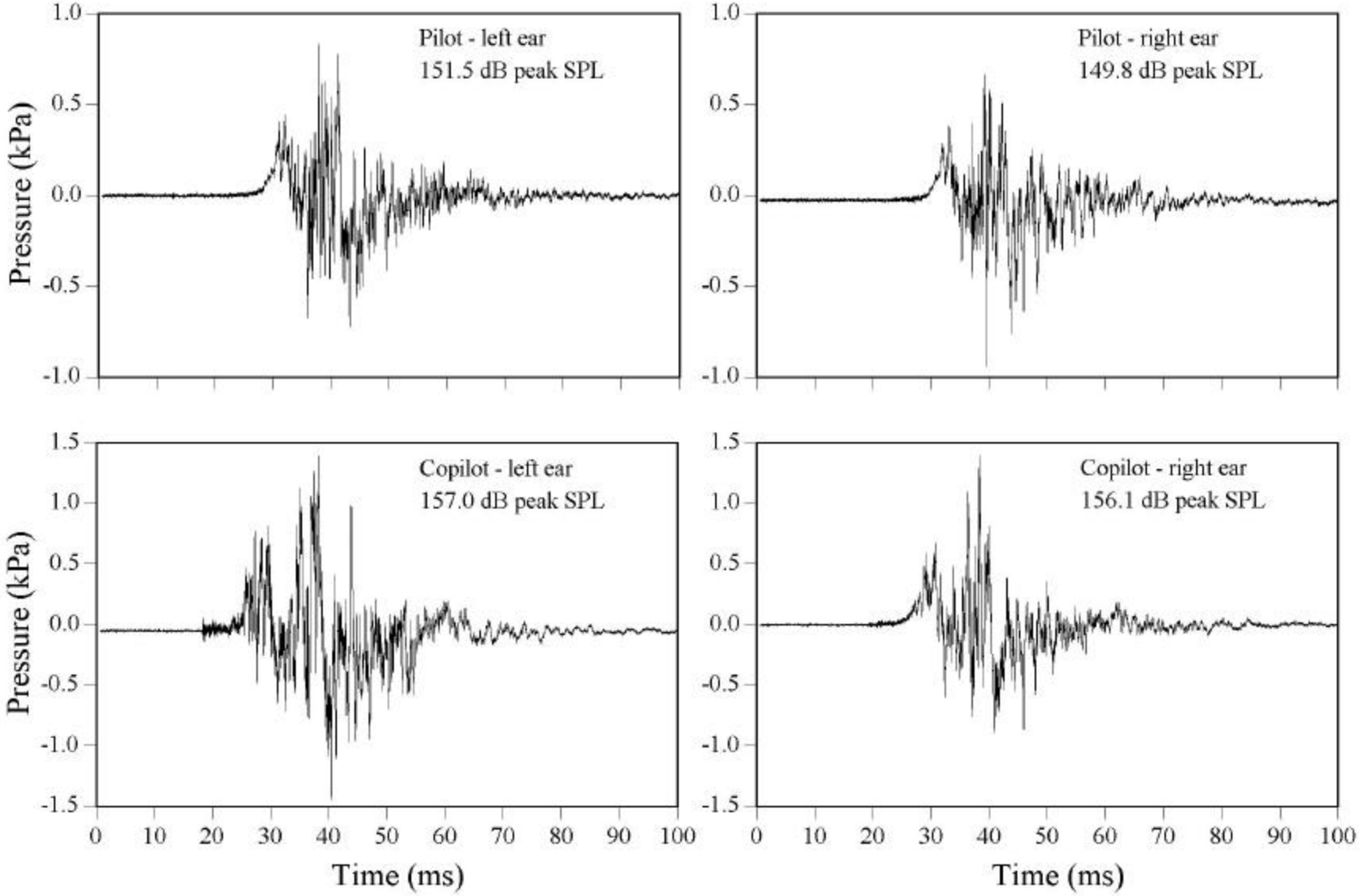

Figure A-1. LLAT06: Pressure-time histories and peak impulse noise levels – left enhanced lateral air bag deployment.

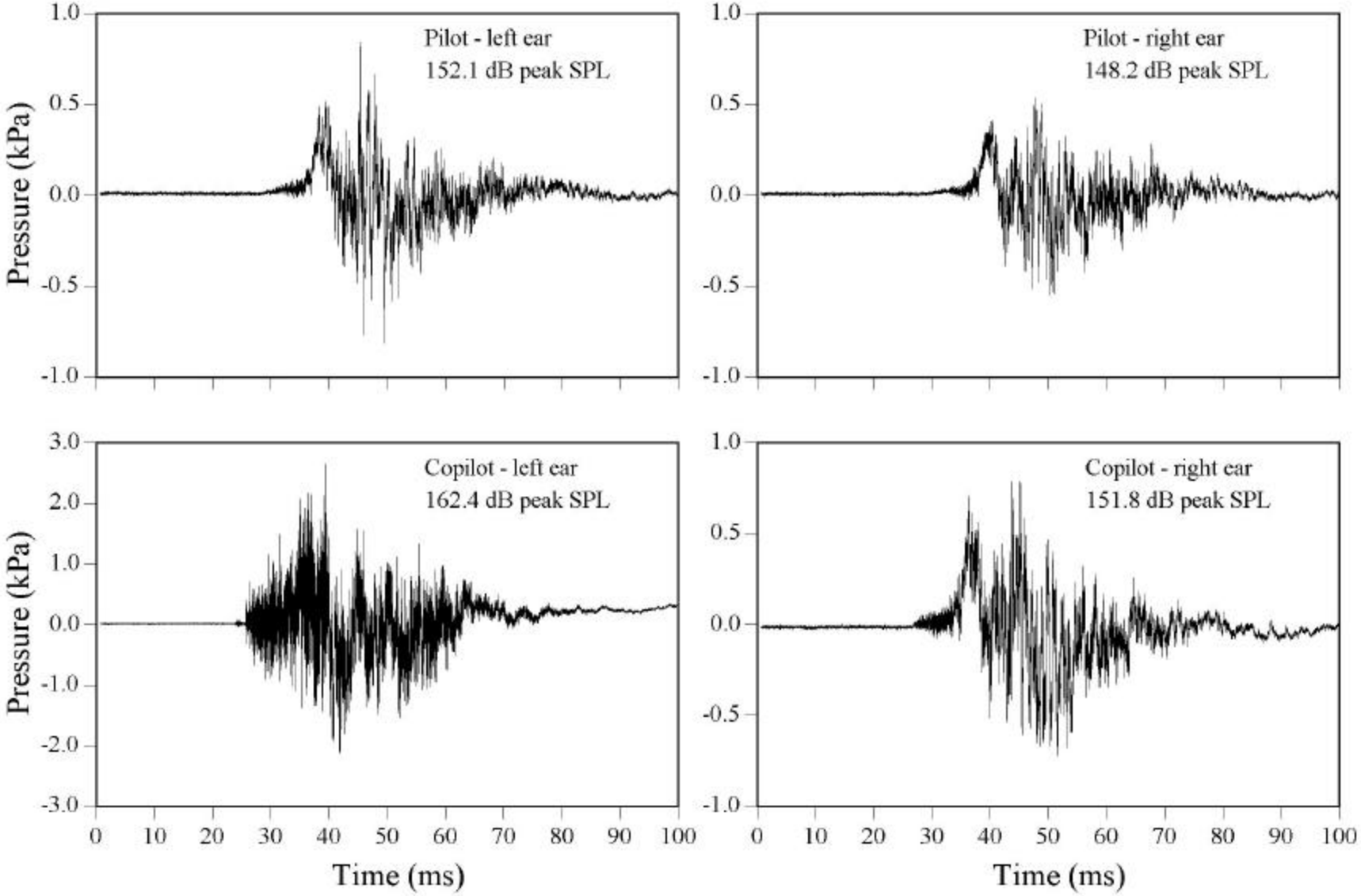

Figure A-2. LLAT07: Pressure-time histories and peak impulse noise levels – left enhanced lateral air bag deployment.

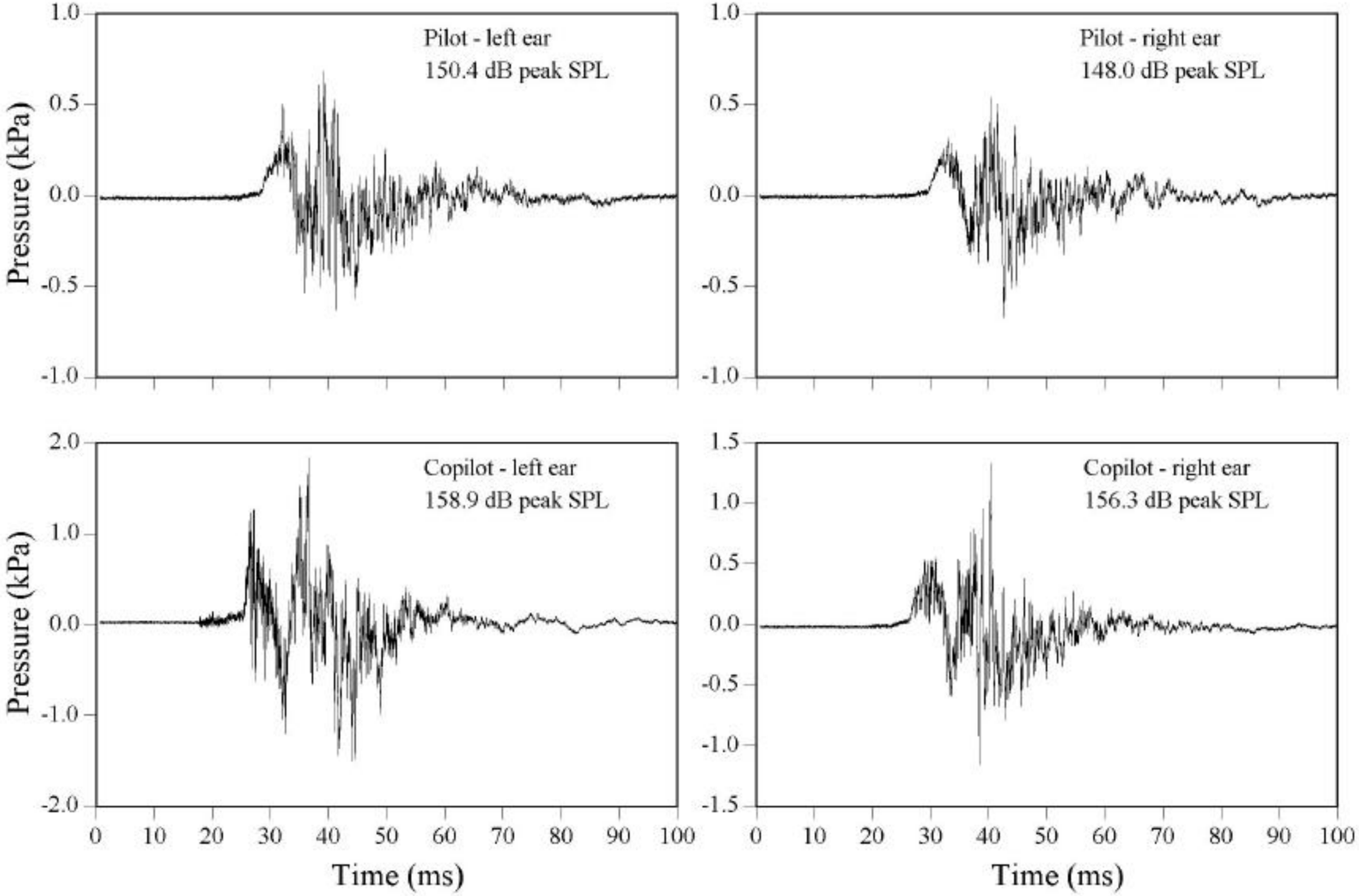

Figure A-3. LLAT08: Pressure-time histories and peak impulse noise levels – left enhanced lateral air bag deployment.

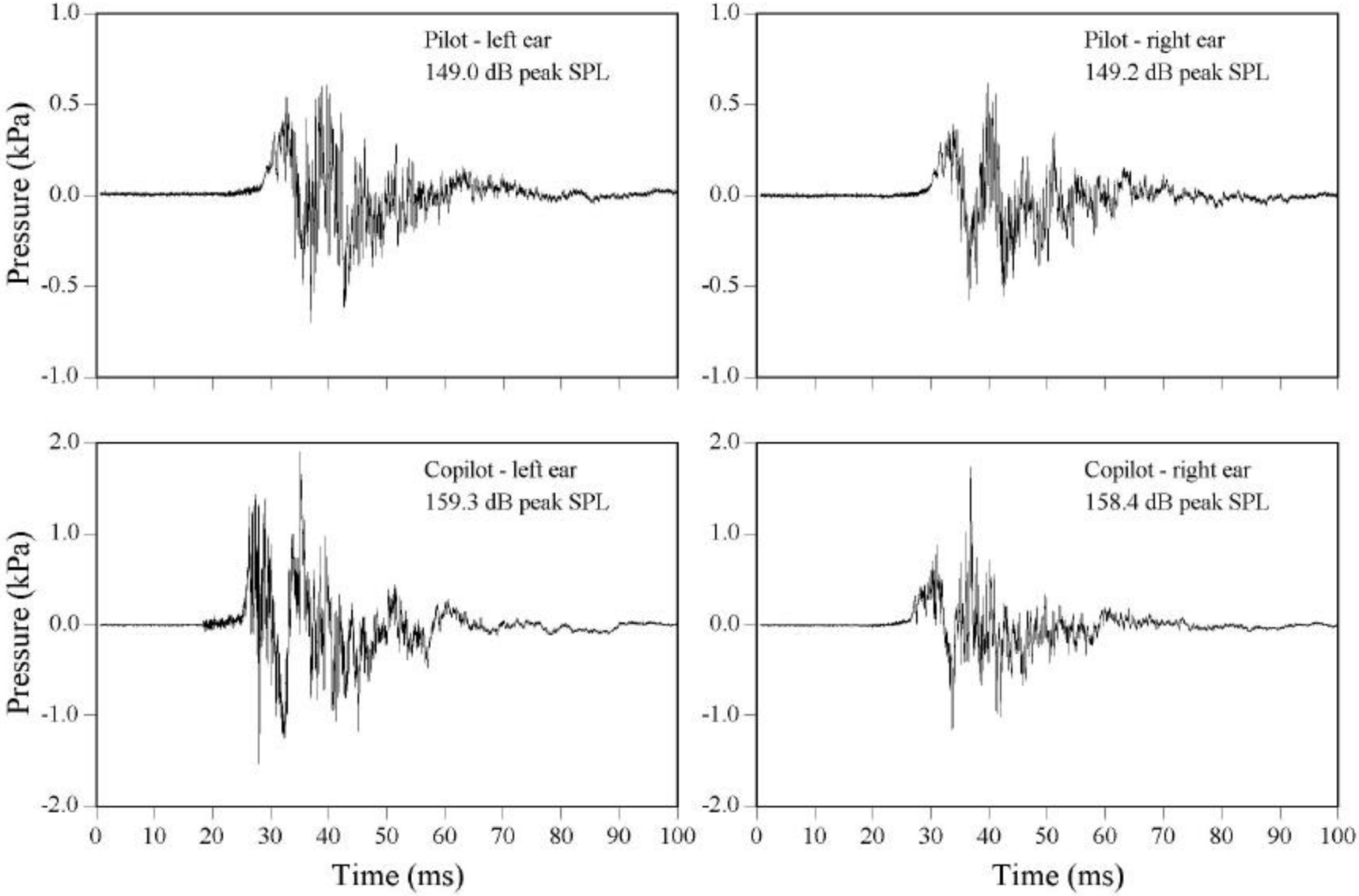

Figure A-4. LLAT09: Pressure-time histories and peak impulse noise levels – left enhanced lateral air bag deployment.

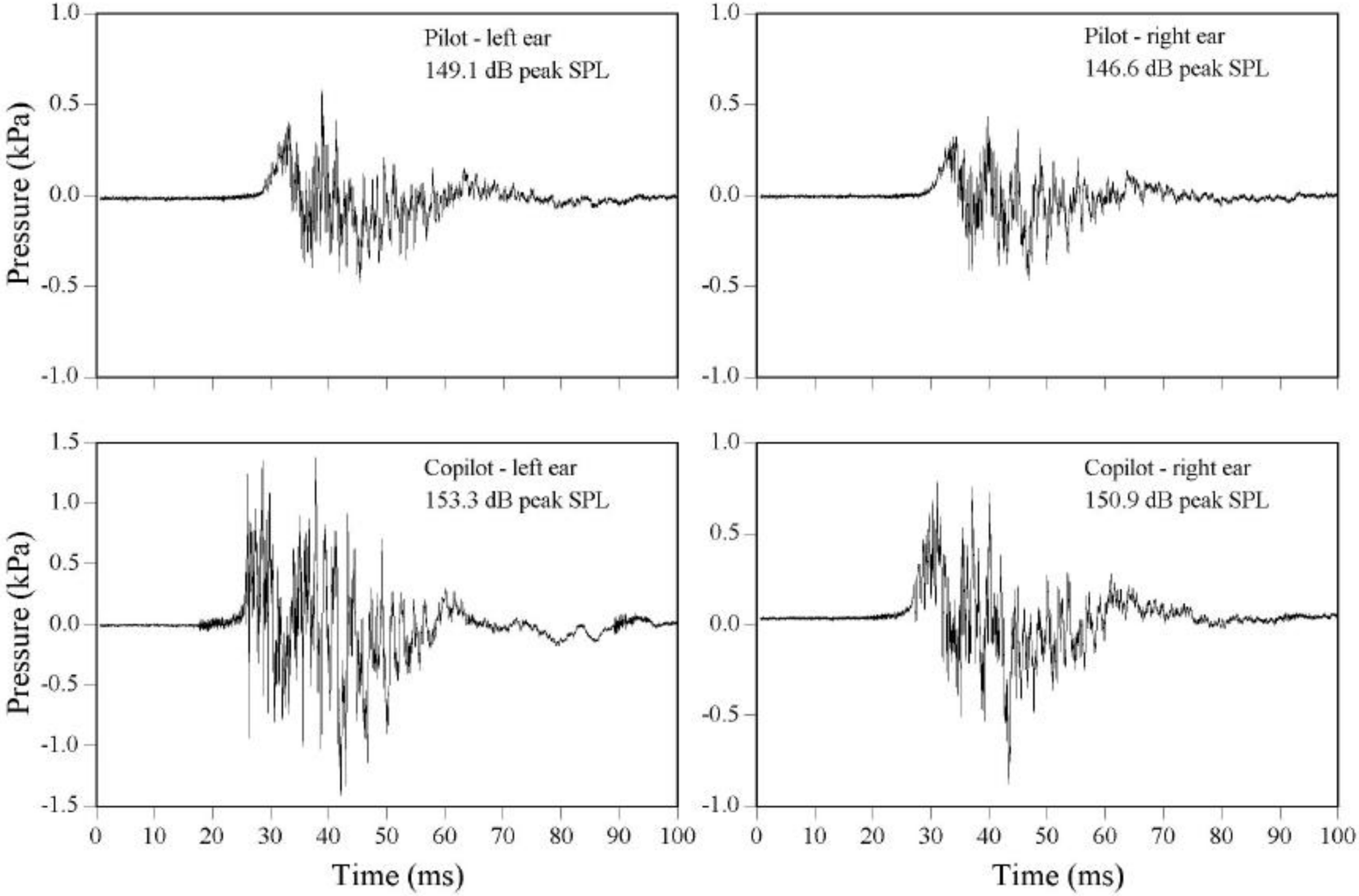

Figure A-5. LLAT10: Pressure-time histories and peak impulse noise levels – left enhanced lateral air bag deployment.

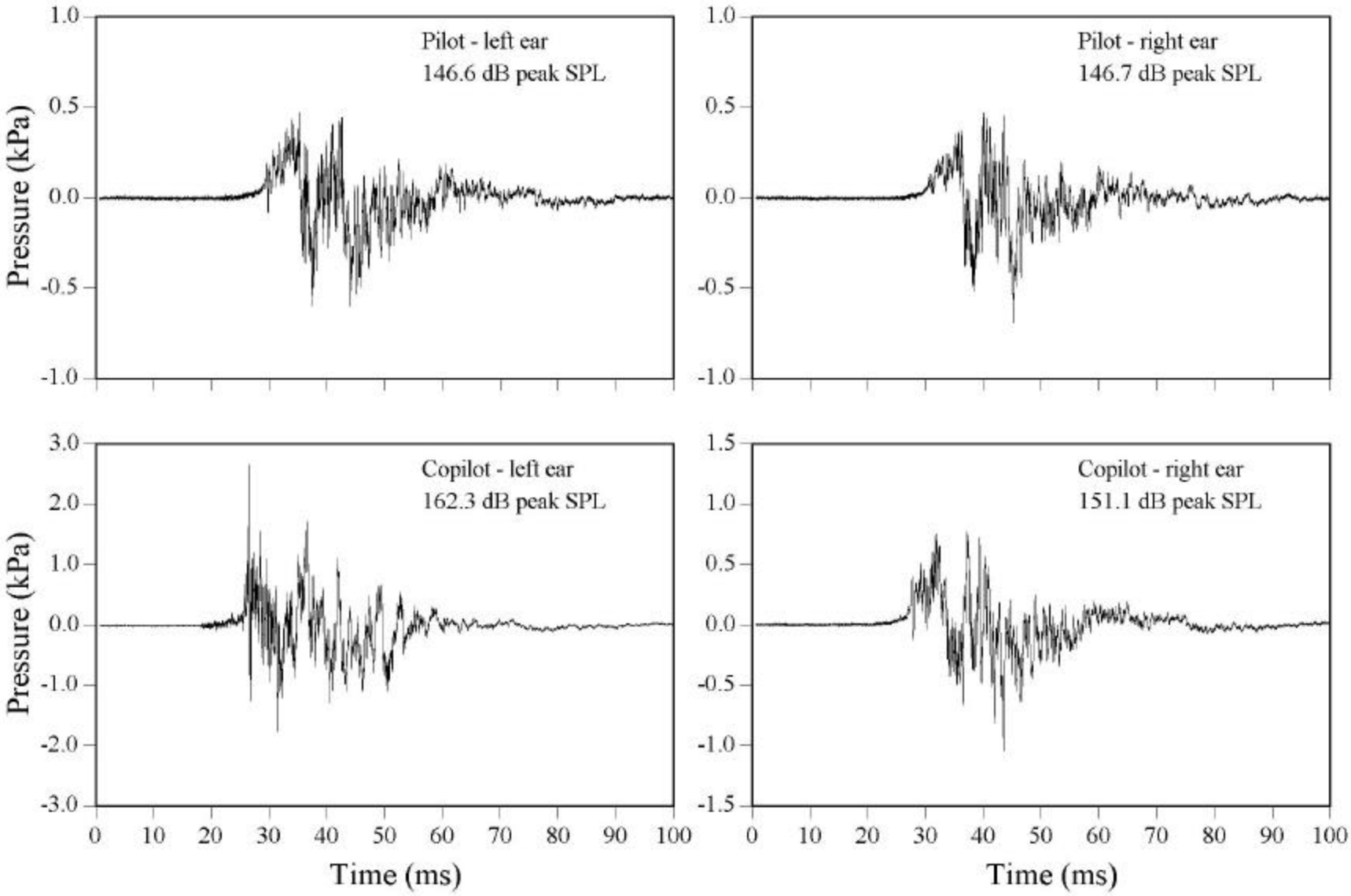

Figure A-6. LLAT11: Pressure-time histories and peak impulse noise levels – left enhanced lateral air bag deployment.

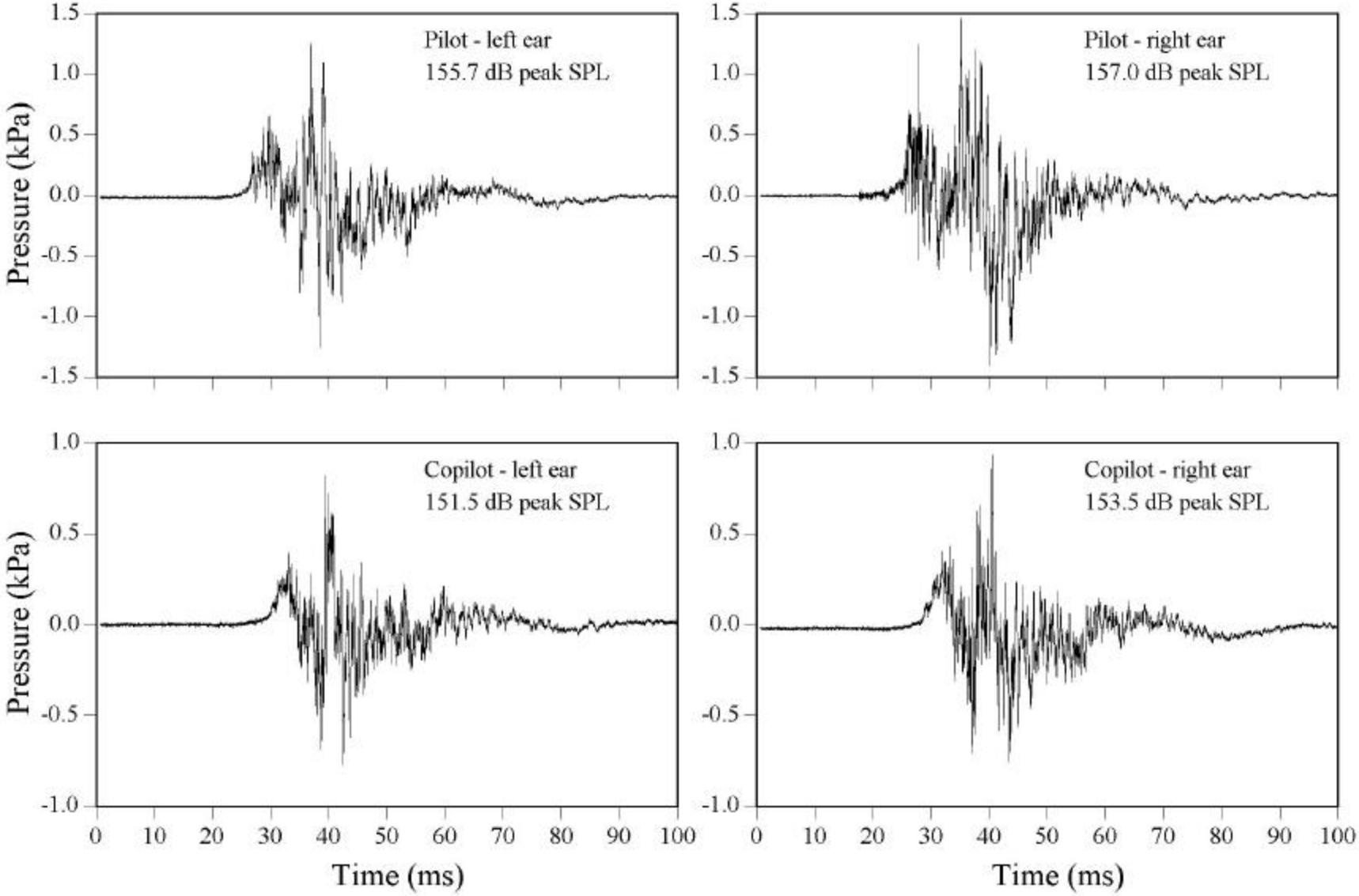

Figure A-7. RLAT06: Pressure-time histories and peak impulse noise levels – right enhanced lateral air bag deployment.

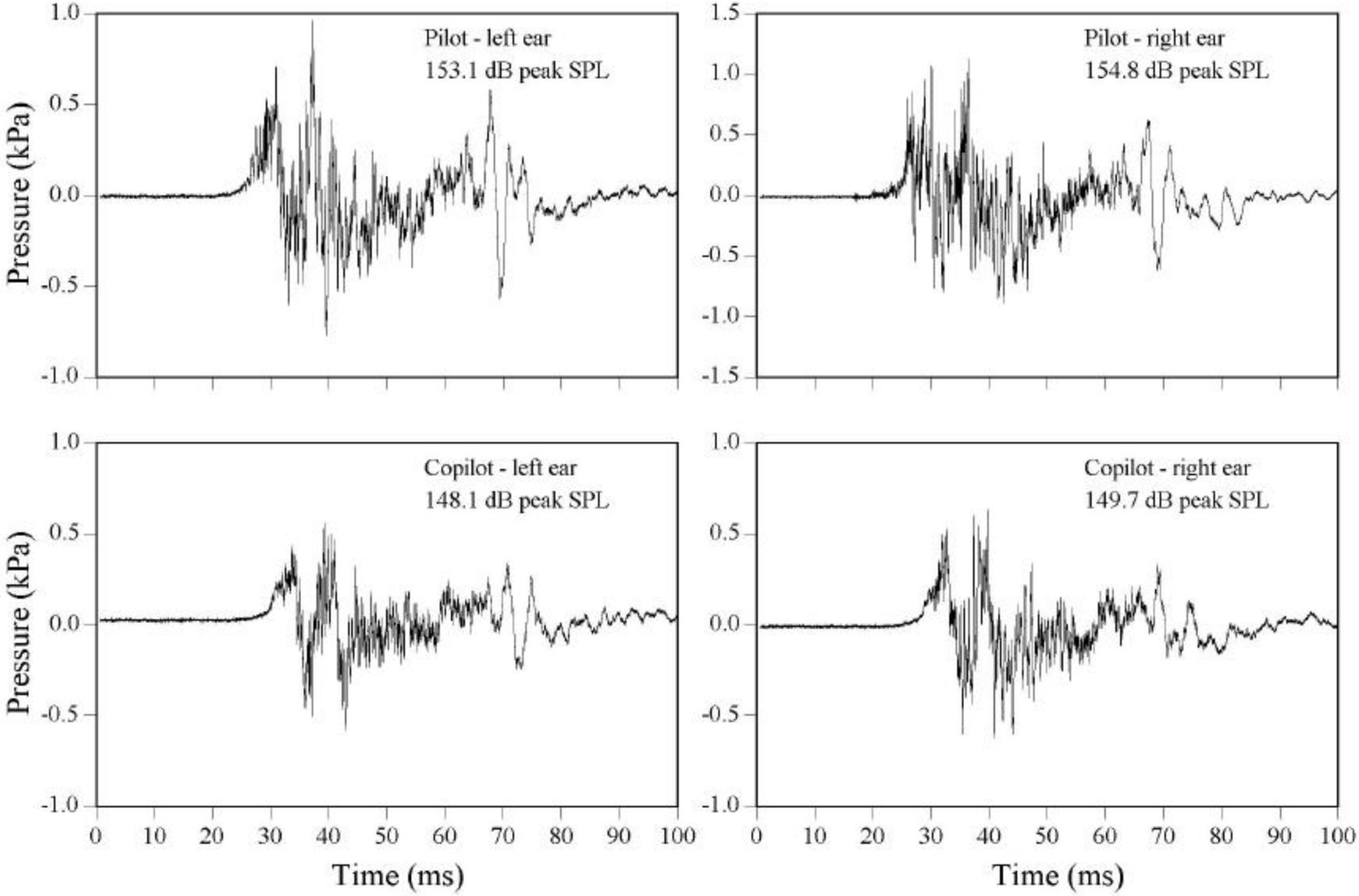

Figure A-8. RLAT07: Pressure-time histories and peak impulse noise levels – right enhanced lateral air bag deployment.

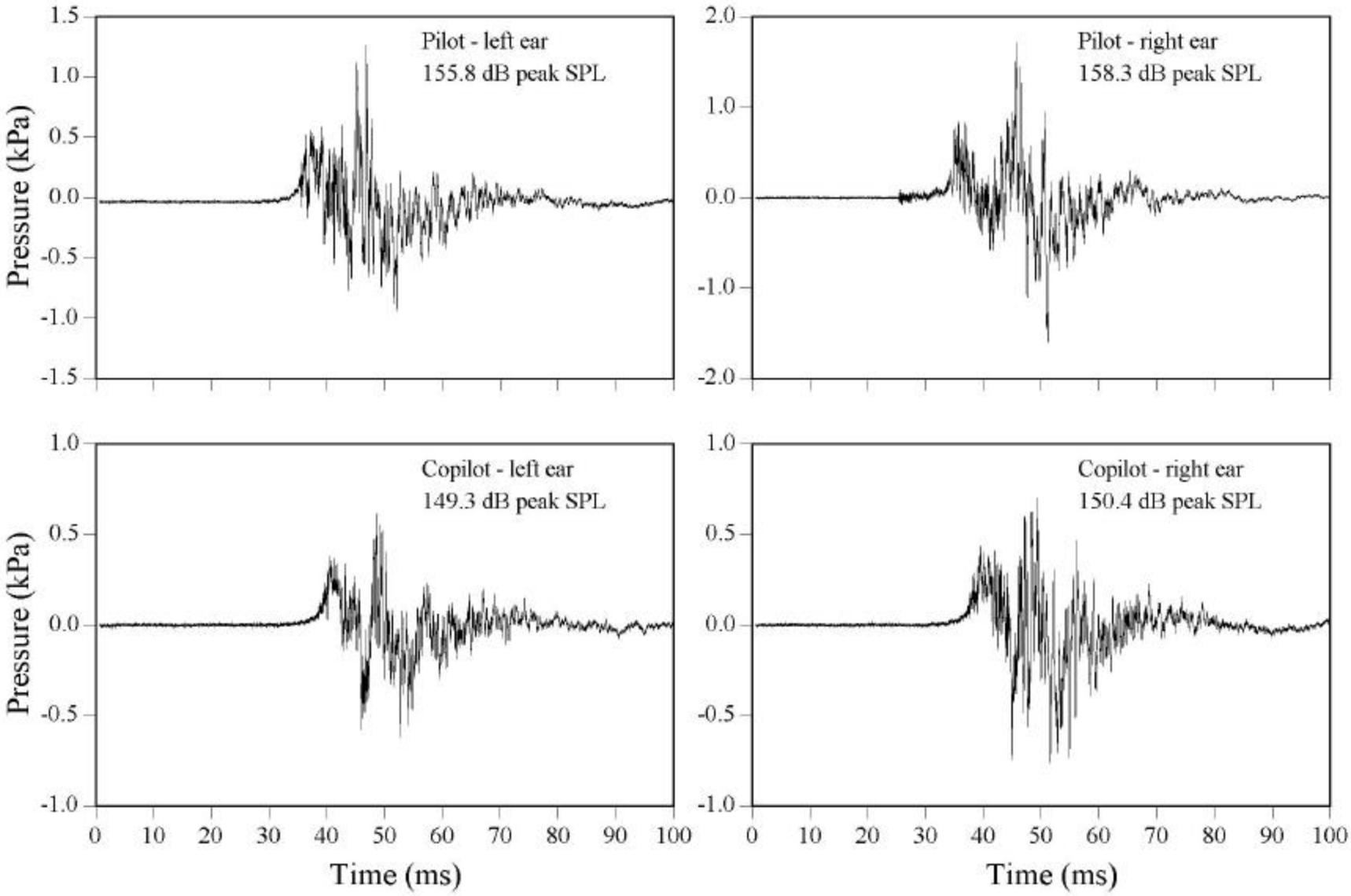

Figure A-9. RLAT08: Pressure-time histories and peak impulse noise levels – right enhanced lateral air bag deployment.

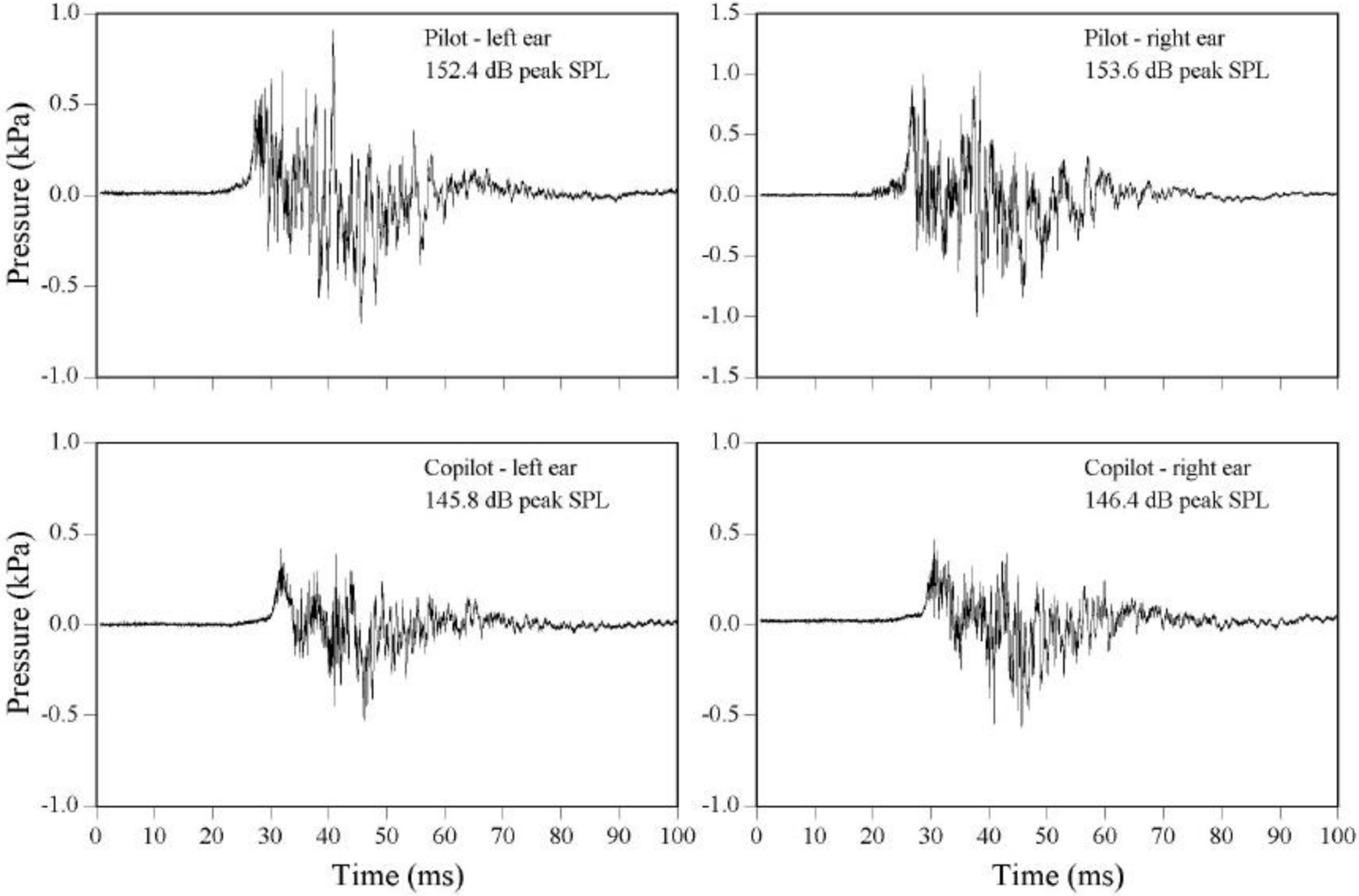

Figure A-10. RLAT09: Pressure-time histories and peak impulse noise levels – right enhanced lateral air bag deployment.

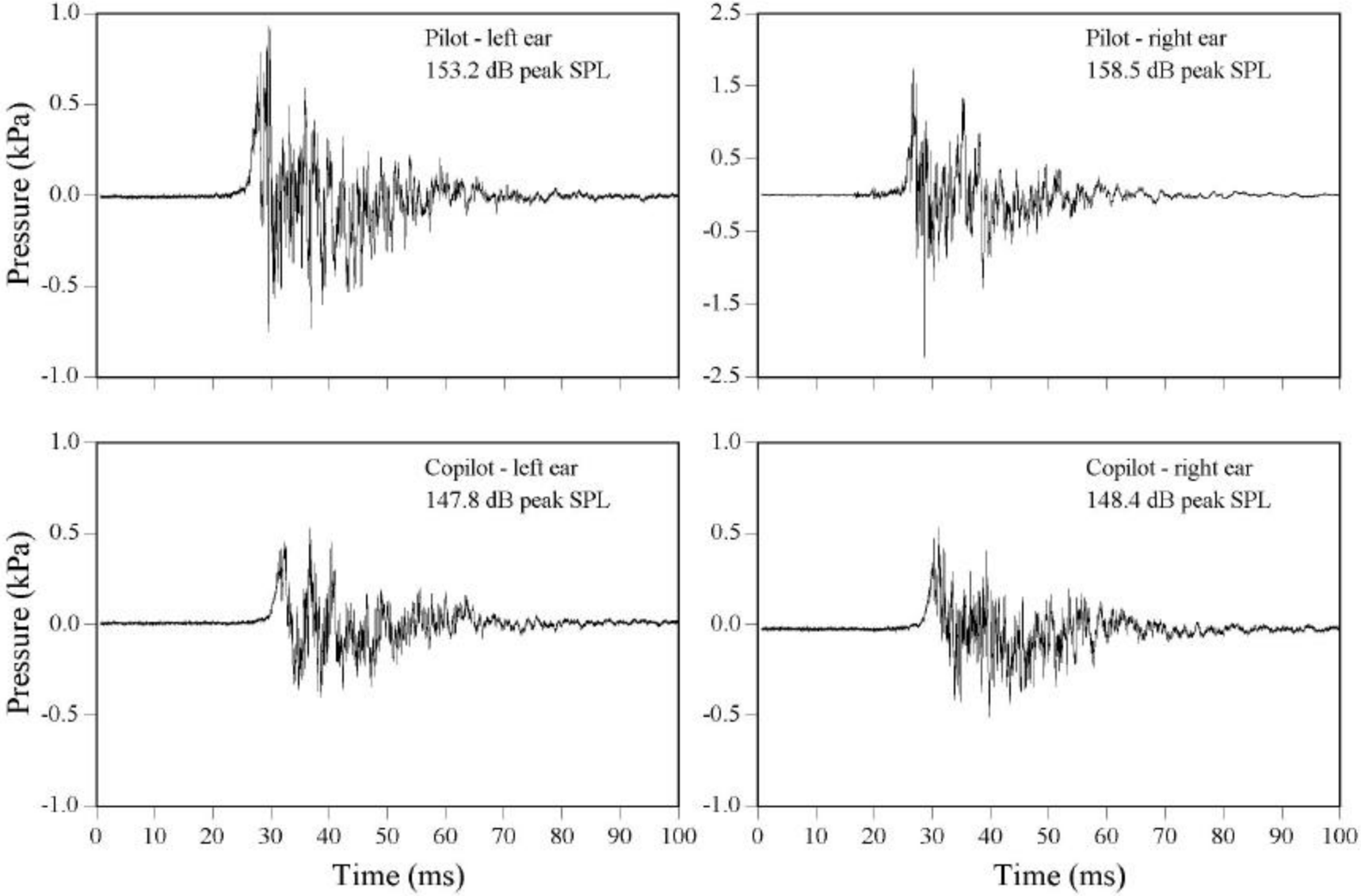

Figure A-11. RLAT10: Pressure-time histories and peak impulse noise levels – right enhanced lateral air bag deployment.

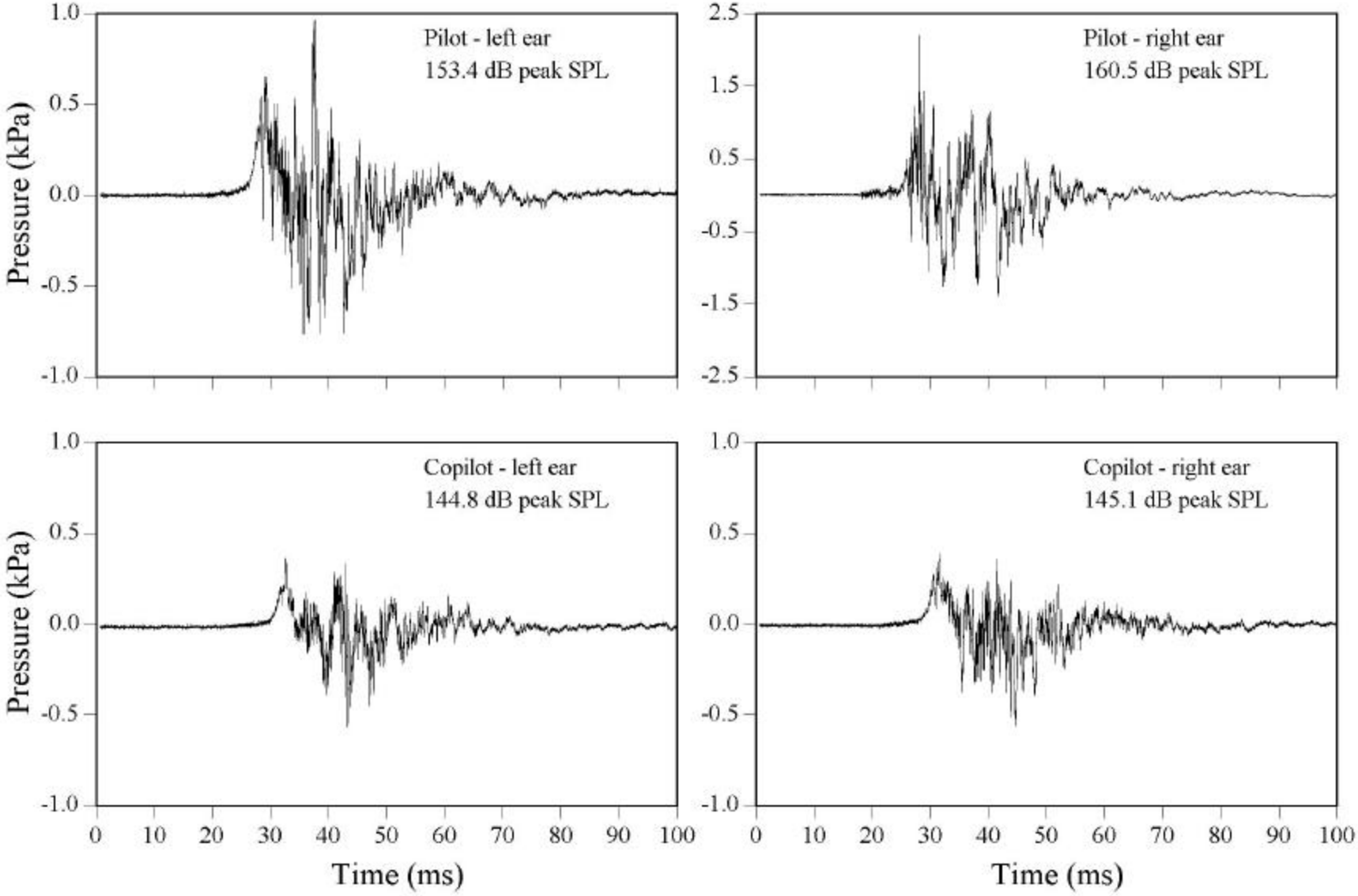

Figure A-12. RLAT11: Pressure-time histories and peak impulse noise levels – right enhanced lateral air bag deployment.

Appendix B.

List of manufacturers.

Bruel & Kjaer North America Inc.
2815-A Colonnades Court
Norcross, Georgia 30071-1588
Phone: 800-332-2040
Fax: 800-236-8351
Email: bkinfo@bksv.com

IOtech, Inc.
25971 Cannon Road
Cleveland, OH 44146
Phone: 440-439-4091
Fax: 440-439-4093
Email: sales@iotech.com

First Technology Safety Systems
47460 Galleon Drive
Plymouth, MI 48170
Phone: 734-451-7878
Fax: 734-451-9549
Email: sales@ftss.com

PCB Piezotronics, Inc.
3425 Walden Avenue
Depew, NY 14043-2495 USA
Phone: 716-684-0001
Fax: 716-684-0987
E-mail: sales@pcb.com

Frequency Devices, Inc.
25 Locust Street
Haverhill, MA 01830
Phone: 800-252-7074
Fax: 508-374-0761
Email: sales@freqdev.com

Robert A. Denton, Inc.
2967 Waterview Drive
Rochester Hills, MI 48309
Phone: 248-852-5100
Fax: 248-852-6060
Email: info@radenton.com